North Coast TSA inventory audit

Introduction

The Ministry of Forests conducts an inventory of each timber supply area (TSA) in British Columbia every 10 to 30 years—using standards and procedures developed by the Resources Inventory Program. Regular updates are undertaken to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within the North Coast TSA. The North Coast TSA is situated along the coastal portion of the Prince Rupert Forest Region, stretching from Meyers Passage (Klemtu) in the south to Stewart in the north. The TSA covers 1 947 531 hectares (ha), and contains the city of Prince Rupert, the District of Port Edward, the Village of Port Simpson and many small coastal communities. Its boundaries coincide with those of the North Coast Forest District, excluding the Stewart area and its environs, which lie in the Kalum Forest District, Tree Farm Licence (TFL) 25, and a few areas of private and reserve lands. The TSA is administered from the North Coast Forest District office in Prince Rupert.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests, and non-forest areas.

The objective of the inventory audit program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the Chief Forester when determining the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

Methods

Current inventory

There are 37 TSAs in British Columbia, varying in size from approximately 70 000 hectares to 13 million hectares. Inventories of each TSA are conducted through a multistage process. Polygons are first delineated from 1:15 000-scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model.

To keep estimates current, inventories are regularly updated to account for forest growth and for depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visitation, satellite imagery, and aerial photographs may be used to update the inventory for depletions.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas

(forest stands older than 60 years). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TSA (*the inventory volume*), is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (*the audit volume*).

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TSA.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias*: This is caused by incorrectly estimating the polygon attributes; or
- *model bias*: This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TSA called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Immature component assessment criteria

Examining the site index assignment tests accuracy of the inventory classification for immature stands. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated using a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

North Coast TSA audit sampling procedures

The North Coast TSA sample used maps from an inventory conducted in 1970's and updated for growth and depletions. Polygons were systematically selected from this list by a process designed to produce a representative sample of the TSA.

For the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TSA was selected for sampling.

For this particular management unit, two inventories were tested. The original inventory of the 1970's and the latest inventory completed in 1996.

Up to 4 full-measure prism plots and 5 count plots were established within each of the 50 polygons that were sampled. The plots were located systematically, using a square grid and a random start point. The grid interval varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. The intent was to establish a total of about 200 full-measure and 250 count plots. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes produced from the VDYP computer yield model.

The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10 cm diameter inside-bark top, a 30 cm

high stump, and decay (as estimated from Ministry loss factors). Dead potential and veteran trees are not included in the VDYP estimates. This volume is calculated for a utilization standard defined as all live trees of 17.5+ cm dbh. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the inventory volume estimates (from VDYP) to test the validity of the current inventory. A paired comparison *t*-test was used to test for significant differences. The precision of the inventory volume estimates—how well each inventory volume estimate corresponds to the audit volume estimate on a sample-by-sample basis—was assessed by measuring the statistical correlation. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons was selected for sampling. Up to 9 inventory ground calls were established within each of the 20 sample polygons. The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. A total of about 114 ground calls were established and data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component of the inventory should be used with caution.

The non-forest component, which is a minor component of the audit, was not completed for this study.

Problems with collected ground data

In every audit, there are unforeseeable problems in the field. The ground data collected in the field is quite extensively quality assured. However, samples were removed from the overall number of samples for the final analysis. The main reasons for reducing from the number of samples analysed are as follows:

- Dropped plots due to extreme slopes and risk to crew safety.
- Dropped plots due to poor crew tie point positioning
- Dropped plots due to field crews misunderstanding sampling procedures

Due to the above issues, Ministry of Forests staff reviewed the entire study, and corrected any anomalies. Seven samples were removed due to the unacceptable bias they cause in the analysis. The 7 samples dropped from the audit were located in the inoperable landbase. Due to the impact of dropping the samples, the audit did not sample 100 percent of the population. It is estimated that only 86 percent of the population was sampled.

The audit process was reviewed and audited by Dr. Don Munro, formerly of UBC. He found the process and procedure acceptable.

Inventory audit results

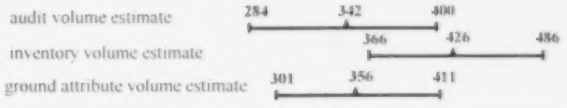
Analysis of mature volumes for the original inventory

Results of the inventory audit for mature volume at the 17.5+ cm dbh utilization limit for the total forested area are given in Table 1.

Table 1. Statistics for original inventory: audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), North Coast TSA

	Audit volume estimate	Inventory volume estimate	Ground attribute volume estimate
Mean of samples	43	43	43
Mean (m3/ha)	342	426	356
Coefficient of variation (%)	55	46	50
Standard error	28.8	29.9	27.4
Sampling error (%)	17.0	14.2	15.5
95% confidence interval (m3/ha)	284-400	366-486	301-411
Correlation coefficient	r = 0.407		
Ratio of means (audit/inventory):	0.80		

Bar graph representation of 95% confidence intervals (in m^3/ha):



The correlation coefficient of 0.407 for the audit and inventory estimates indicates a moderate relationship among the individual samples. There is an 84 m^3/ha difference between the mean inventory estimate for mature volume (426 m^3/ha) and the audit estimate (342 m^3/ha). A paired-sample *t*-test determined that, for the mature component of the total forested area of the TSA, this difference is statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is –148 to –19 m^3/ha.

Since there is statistical difference between the two estimates, the ground attribute volume was calculated using

the VDYP model. The estimated mean ground attribute volume is 356 m^3/ha. The difference between the mean ground attribute volume and the mean audit volume is 14 m^3/ha. The difference between the mean ground attribute volume and the inventory volume is 70 m^3/ha. This suggests that there is a significant bias associated with the inventory attributes in the original inventory.

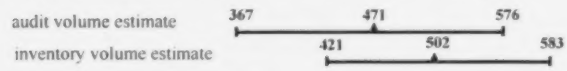
Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (operable areas). The operable volumes are not directly linked to the Timber Supply Review as they undergo further net downs to achieve the net harvestable land base. The audit results were post-stratified based on this approximation. Results of the inventory audit for samples in the operable forested areas in the TSA based on the original inventory are given in Table 2 and inoperable forested area in Table 3.

Table 2. Statistics for original inventory: audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), operable forested areas, North Coast TSA

	Audit volume estimate	Inventory volume estimate
Mean of samples	11	11
Mean (m3/ha)	471	502
Coefficient of variation (%)	33	24
Standard error	46.9	36.4
Sampling error (%)	22.2	16.2
95% confidence interval (m3/ha)	367-576	421-583
Correlation coefficient	r = 0.134	
Ratio of means (audit/inventory):	0.94	

Bar graph representation of 95% confidence intervals (in m^3/ha):

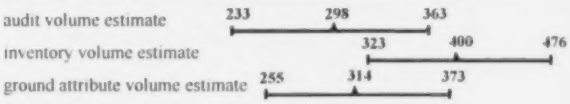


For the 11 samples located within the operable forested area, the mean audit volume is 471 m^3/ha and mean inventory volume is 502 m^3/ha. The difference between these two estimates (31 m^3/ha) is not statistically significant, 19 times out of 20. However, due to the small sample size, these conclusions must be viewed with caution.

Table 3. Statistics for original inventory on the audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), inoperable forested areas, North Coast TSA

	Audit volume estimate	Inventory volume estimate	Ground attribute volume estimate
Mean of samples	32	32	32
Mean (m3/ha)	298	400	314
Coefficient of variation (%)	61	53	52
Standard error	31.9	37.3	28.9
Sampling error (%)	21.8	19.1	18.8
95% confidence interval (m3/ha)	233-363	323-476	255-373
Correlation coefficient	r = 0.391		
Ratio of means (audit/inventory):	0.75		

Bar graph representation of 95% confidence intervals (in m^3/ha):



For 32 samples located within the inoperable forested area, the mean audit volume is 298 m^3/ha and mean inventory volume is 400 m^3/ha. The mean difference of 102 m^3/ha between these two estimates, is statistically significant, 19 times out of 20. The mean estimated ground attribute volume was 314 m^3/ha. This suggests that for inoperable areas in the original inventory of the North Coast TSA, the majority of the total bias is associated with the attributes.

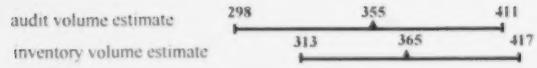
Analysis of mature volumes for the new inventory

A new inventory was completed between 1994 and 1996. The audit samples were stratified to the new inventory. There was one less sample in the new inventory. One sample that was valid in the original inventory was now considered non-productive. Results of the audit for the new inventory, mature volume at 17.5+ cm dbh utilization limit for the total forested area are given in Table 4.

Table 4. Statistics for new inventory on the audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), forested areas, North Coast TSA

	Audit volume estimates	Inventory volume estimate
Mean of samples	42	42
Mean (m3/ha)	355	365
Coefficient of variation (%)	51	46
Standard error	27.0	25.8
Sampling error (%)	15.9	14.3
95% confidence interval (m3/ha)	298-411	313-417
Correlation coefficient	r = 0.645	
Ratio of means (audit/inventory):	0.97	

Bar graph representation of 95% confidence intervals (in m^3/ha):



The correlation coefficient of 0.645 for the audit and inventory estimates indicates a strong relationship among the individual samples. There is a 10 m^3/ha difference between the mean inventory estimate for mature volume (365 m^3/ha) and the audit estimate (355 m^3/ha). A paired-sample *t*-test determined that, for the mature component of the total forested area of the TSA, based on the new inventory, this difference is not statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is –56 to +36 m^3/ha.

Since there is no statistical difference between the two estimates, the ground attribute volume was not calculated.

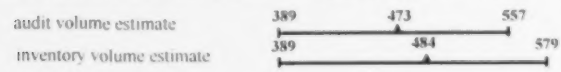
Analysis of operable and inoperable volumes in the new inventory

The audit samples were stratified for the new inventory into operable and inoperable for the forested areas, and are given in Table 5 and 6.

Table 5. Statistics for new inventory on the audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), operable forested areas, North Coast TSA

	Audit volume estimates	Inventory volume estimate
Mean of samples	14	14
Mean (m3/ha)	473	484
Coefficient of variation (%)	31	34
Standard error	38.0	44.1
Sampling error (%)	17.7	19.7
95% confidence interval (m3/ha)	389-557	389-579
Correlation coefficient	r = 0.448	
Ratio of means (audit/inventory):	0.98	

Bar graph representation of 95% confidence intervals (in m^3/ha):

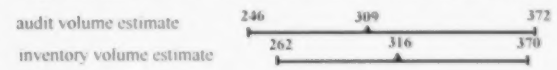


For the 14 samples located within the operable forested area, the means audit volume is 473 m^3/ha and the mean inventory volume is 484 m^3/ha. The difference between these two estimates of 11 m^3/ha, is not statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is –106 to +84 m^3/ha. However, due to the small sample size, these conclusions must be viewed with caution.

Table 6. Statistics for new inventory on the audit volume and inventory volume estimates at 17.5+ cm dbh utilization (net decay waste and breakage), inoperable forested areas, North Coast TSA

	Audit volume estimates	Inventory volume estimate
Mean of samples	31	31
Mean (m3/ha)	309	316
Coefficient of variation (%)	55	46
Standard error	30.7	26.4
Sampling error (%)	20.3	17.1
95% confidence interval (m3/ha)	246-372	262-370
Correlation coefficient	r = 0.604	
Ratio of means (audit/inventory):	0.98	

Bar graph representation of 95% confidence intervals (in m^3/ha):



For 31 samples located within the inoperable forested area, the mean audit volume is 309 m^3/ha and mean inventory volume is 316 m^3/ha. The difference between these two estimates of 7 m^3/ha is not statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is –60 to +45 m^3/ha.

Analysis of immature (original) inventory classification

Out of 20 stands sampled in the field, top height information was not available for one stand and one stand was indicated as NSR on the inventory and hence site index could not be assessed. Of the remaining 18 stands, the inventory correctly identified site index within ±3 m of the audit site index for 5 stands; the inventory site index was more than 3 m lower than the audit site index for 8 stands and more than 3 m higher than the audit site index for 5 stands.

North Coast TSA Ratio of Means Summary

Table 7. Summarization of the Audit Results for the Original Inventory and the New Inventory.

	Original (Old) Inventory			New Inventory		
	All Samples	Operable	In- operable	All Samples	Operable	In- operable
Samples (n)	43	11	32	42	14	31
Mean audit volume (17.5 cm+ dbh, net dwb)	342	471	298	355	473	309
Mean inventory volume (17.5+ dbh net dwb)	426	502	400	365	484	316
Total Bias (ratio of mean audit volume/ha over mean inventory volume/ha)	0.80	0.94	0.75	0.97	0.98	0.98

Note: the sum of the operable and inoperable samples may not equal the total of all samples, since, for the new inventory, samples may contribute to both.

Discussion and conclusions

The objective of the inventory audit in the North Coast TSA was to assess the overall accuracy of the current Ministry of Forests inventory. The mature and immature were tested.

Audit results for the mature component of the original inventory suggest that the inventory volume may be overestimated. The bias in the inventory volume estimate appears to be associated primarily with the original inventory attributes. Subsequent analysis of post-stratified data also shows similar trends in the original inventory for the inoperable forested area. The audit results suggest that the original inventory is statistically acceptable in the operable areas. However, due to the small sample size in this stratum, these conclusions must be viewed with caution.

Analysis of the new inventory indicates that the inventory is statistically acceptable. There is no statistically significant bias associated with the ground attributes for the new inventory

Audit results for the immature component of the original inventory suggest the immature site index assignment may not be accurate. Further review of this component of the inventory is required.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type groups that are further defined by site class, geographic location or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down dead timber which is

estimated to contain at least 50% of its original gross volume in sound wood.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessible location, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

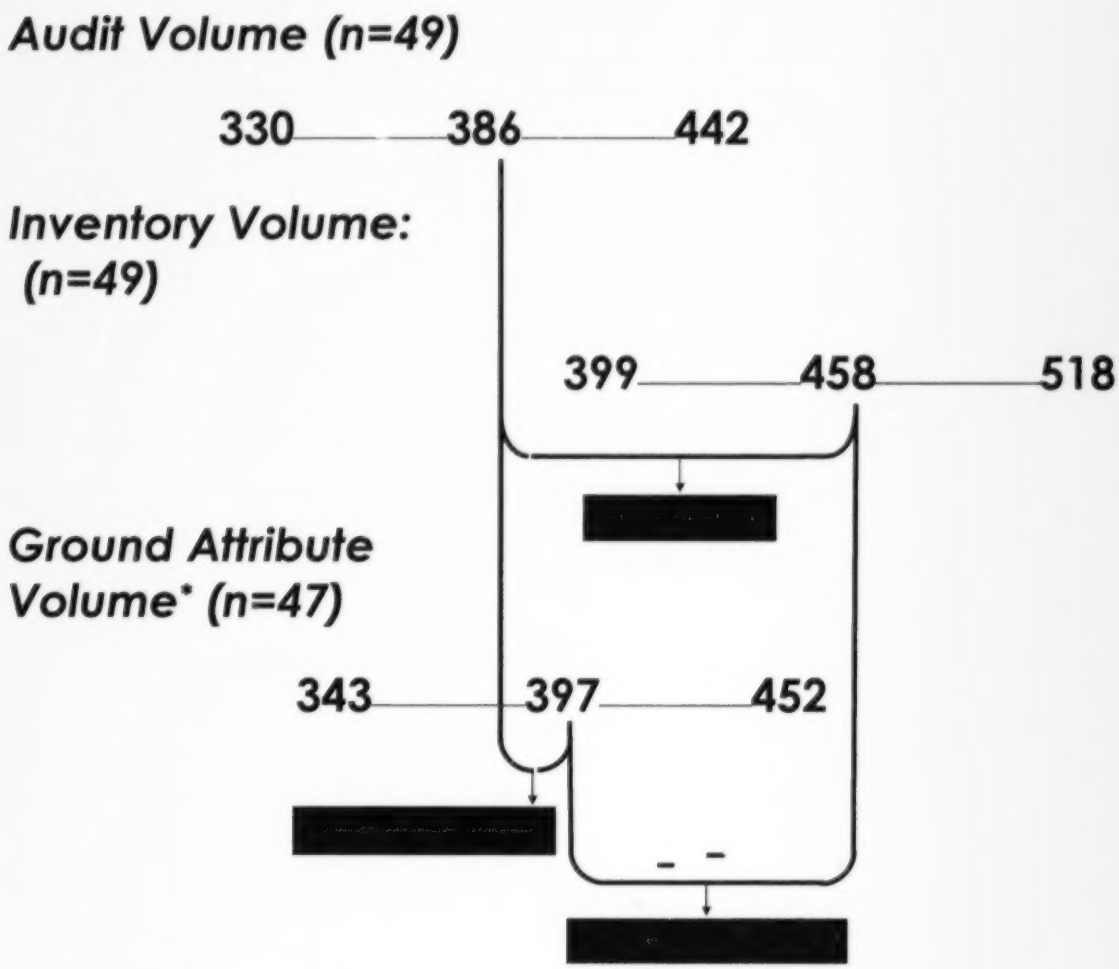
veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, Phone 250-387-1314, fax 250-387-5999, or visit our web site at http://www.for.gov.bc.ca/resinv/

November 1999

Inventory Audit Results:
Overview North Coast TSA
December, 1997



* "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=49)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/Tree Class 1,2)*

330 —— 386 —— 442 Audit Volume (14.6% sampling error)

399 —— 458 —— 518 Inventory Volume (map label attributes predicted in VDYP) (13.1% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.84$

1.0 ↓

0.71 —— 0.84 —— 0.97

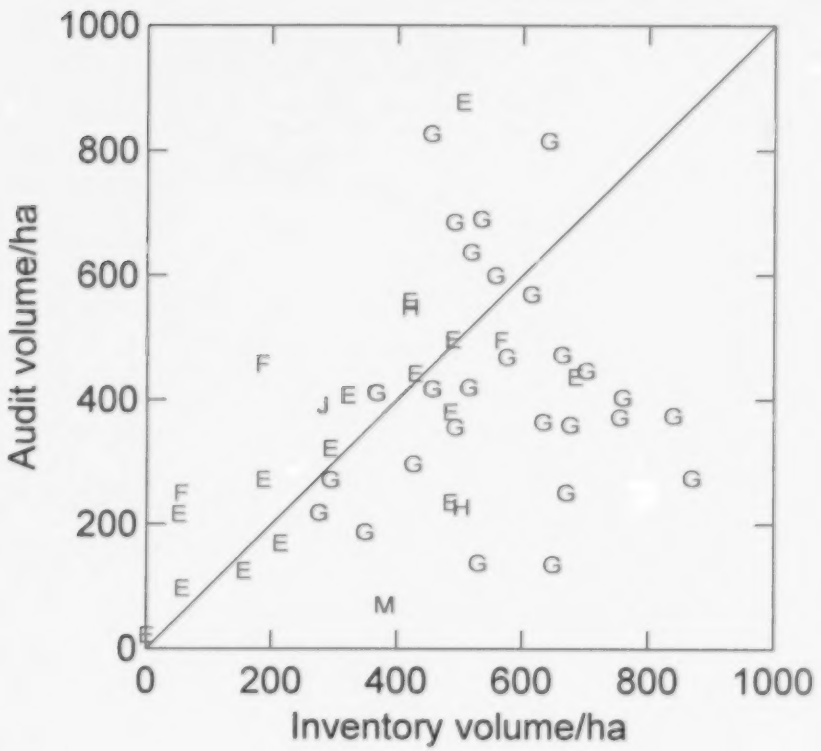
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -72.492 m^3/ha
p - value for mean difference = 0.029
**since p-value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -142.811; p-value = 0.005; n=27)

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.376
p value for correlation co-efficient = 0.008
.: correlation is significant

NORTH COAST TSA Inventory Audit:
Audit Volume vs. Inventory Volume (by GTG)
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): *"VDYP model" bias (n=47*)*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only /Tree class 1,2))*

322 ——— 380 ——— 437 Audit Volume (n=47) (15.1% sampling error)

343 ——— 397 ——— 452 Ground Attribute Volume (predicted in VDYP) (13.7% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R =$ *average audit volume* / *average ground attribute volume predicted in VDYP* $= 0.96$

1.0
↓

0.84 ——— 0.96 ——— 1.07

** Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -17.791 m^3/ha
p - value for mean difference = 0.430
**since p - value > α, the difference is not significant*

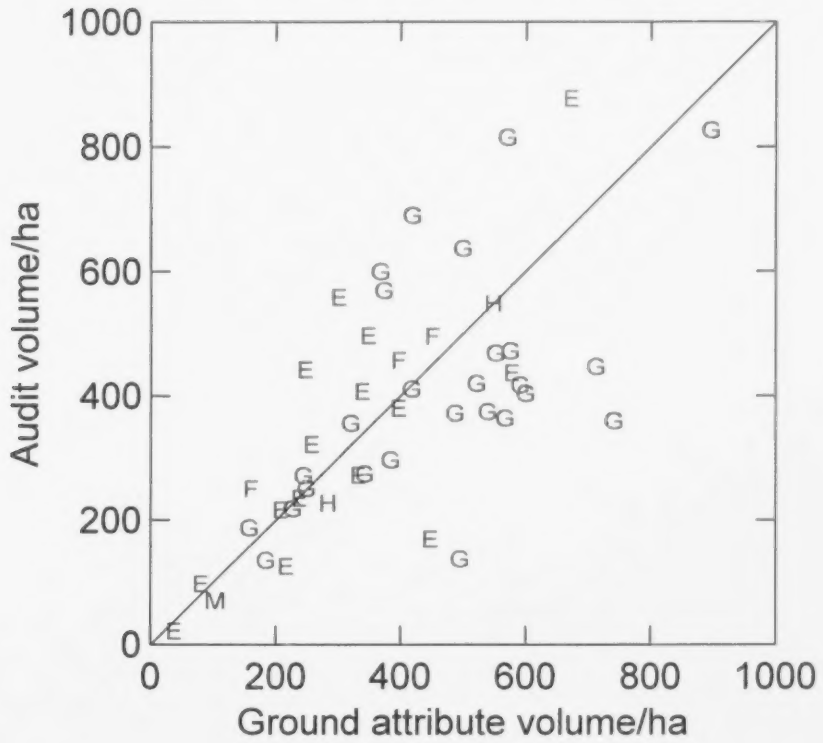
4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG F.
(for GTG F: mean difference = 63.9; p-value = 0.040; n=3)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.678
p - value for correlation co-efficient < 0.001
.: correlation is significant

---

* Top height (and hence ground attribute volume) was not available for 2 samples. All statistics on this page are based on the 47 samples for which both an audit volume and a ground attribute volume was available.

NORTH COAST TSA Inventory Audit:
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): *"Attribute" Bias (n=47*)*

1. Average volumes/ha and confidence interval @ 95%

(Utilization level : 17.5 cm + net merch. less decay only, Tree Class 1,2)]

343 ——— 397 ——— 452

Ground Attribute Volume
(predicted in VDYP)
(13.7% sampling error)

400 ——— 462 ——— 524

Inventory Volume (n=47)
(map label attributes predicted in VDYP)
(13.4% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.86$$

1.0
↓

0.75 ——— 0.86 ——— 0.97

** The ratio indicates that there is a significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -64.232 m^3/ha
p - value for mean difference = 0.022
**since p - value < α, the difference is significant*

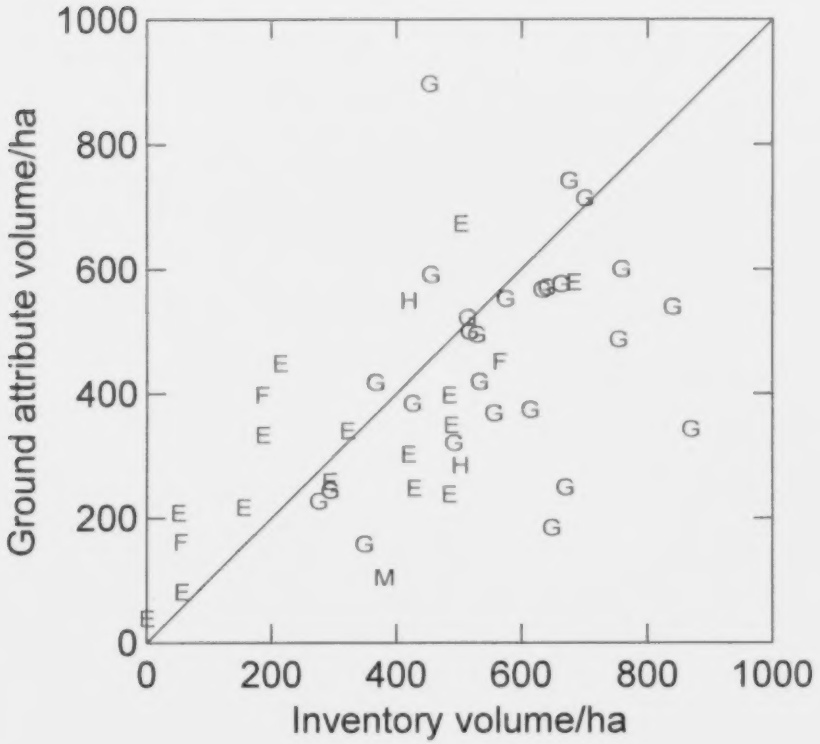
4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -106.715; p-value = 0.011; n=26)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.572
p - value for correlation co-efficient < 0.001
∴ correlation is significant

---

* Top height (and hence ground attribute volume) was not available for 2 samples. All statistics on this page are based on the 47 samples for which both an inventory volume and a ground attribute volume was available.

NORTH COAST TSA Inventory Audit:
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Audit (ground) height (m) vs. Inventory height (m) (n=47*)

1. Average heights and confidence interval @ 95%

21.8 —— 24.1 —— 26.4 Audit (ground) height (9.4% sampling error)

24.8 —— 27.3 —— 29.9 Inventory height (n=47) (9.3% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit height}}{\text{average inventory height}} = 0.88$$

1.0
↓

0.80 —— 0.88 —— 0.96

** The ratio indicates there is a significant difference between the audit height and the inventory height.*

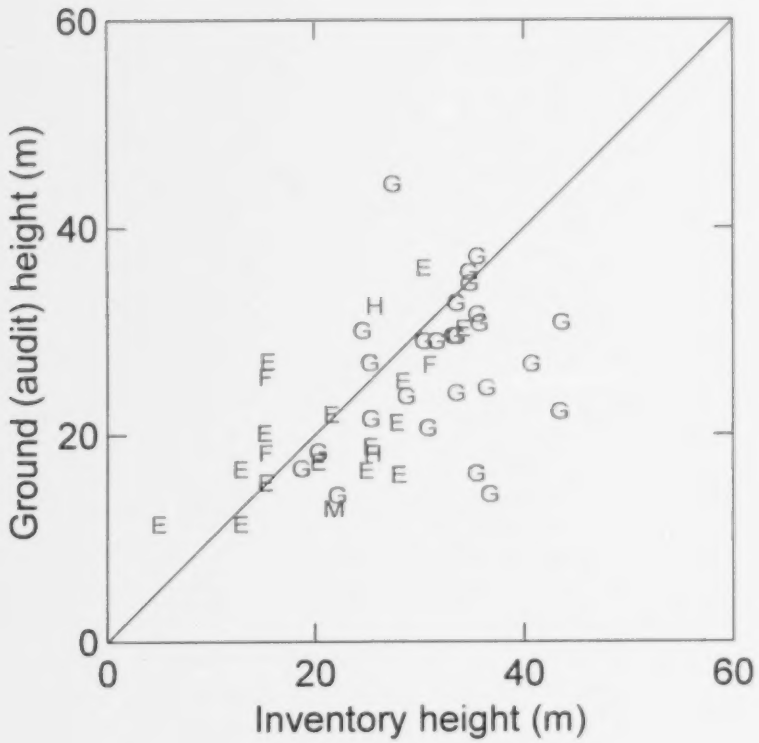
3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons (n=47)
mean difference = -3.209 m
p - value for mean difference = 0.008
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were significant differences for GTG G.
(for GTG G: mean difference = -5.265 m; p - value = 0.004; n=26)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.528
p - value for correlation co-efficient < 0.001
∴ correlation is significant

* There are 47 samples for which there both are inventory attributes (age and height) and valid ground top height and age data.

North Coast TSA Inventory Audit:
Audit (ground) height vs. Inventory height by GTG



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Audit (ground) age (yrs) vs. Inventory age (yrs) (n=47*)

1. Average ages and confidence interval @ 95%

233——249——265

Audit (ground) age
(6.4% sampling error)

294——303——312

Inventory age (n=47)
(2.9% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit age}}{\text{average inventory age}} = 0.82$$

1.0
↓

0.76——0.82——0.88

** The ratio indicates there is a significant difference between the audit age and the inventory age.*

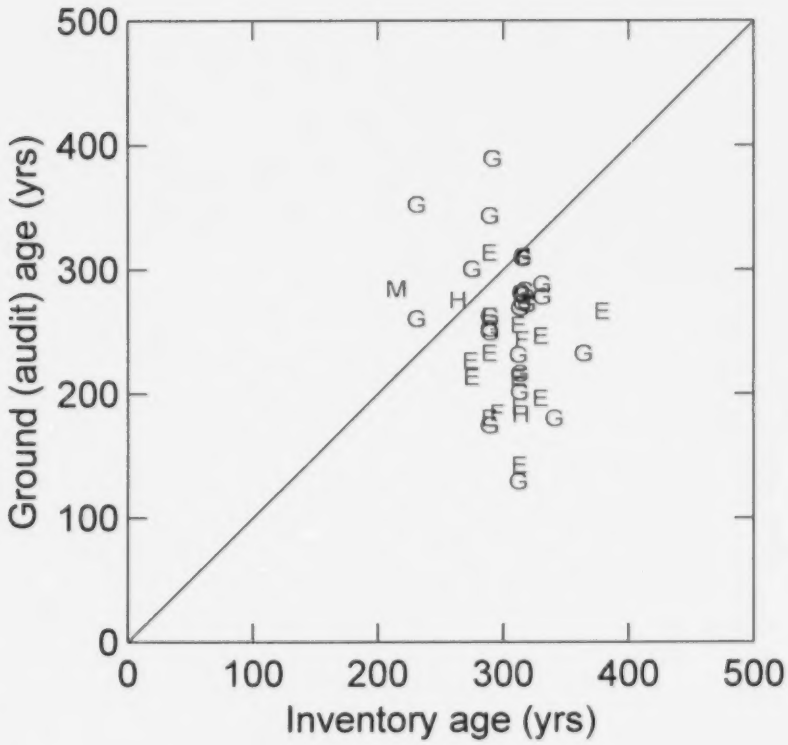
3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons (n=47)
mean difference = -54.426 m
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were significant differences for GTGs G and E.
(for GTG G: mean difference = -40.308 m; p - value = 0.008; n=26
for GTG E: mean difference = -84.667 m; p - value < 0.001; n=15)

5. Correlation @95%($\alpha = 0.05$) for all samples (n=47)
Correlation co-efficient r = -0.201
p - value for correlation co-efficient = 0.175
∴ correlation is NOT significant

* There are 47 samples for which there both are inventory attributes (age and height) and valid ground top height and age data.

North Coast TSA Inventory Audit:
Audit (ground) age vs. Inventory age by GTG



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) for Operable Samples (n=13)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only /Tree Class 1,2)*

363 ——— 457 ——— 550 Audit Volume (20.6% sampling error)

488 ——— 576 ——— 664 Inventory Volume (map label attributes predicted in VDYP) (15.3% sampling error)

2. Ratio Analysis : Ratio of Means @95% (n=13)

$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.79$

1.0 ↓

0.59 ——— 0.79 ——— 0.99

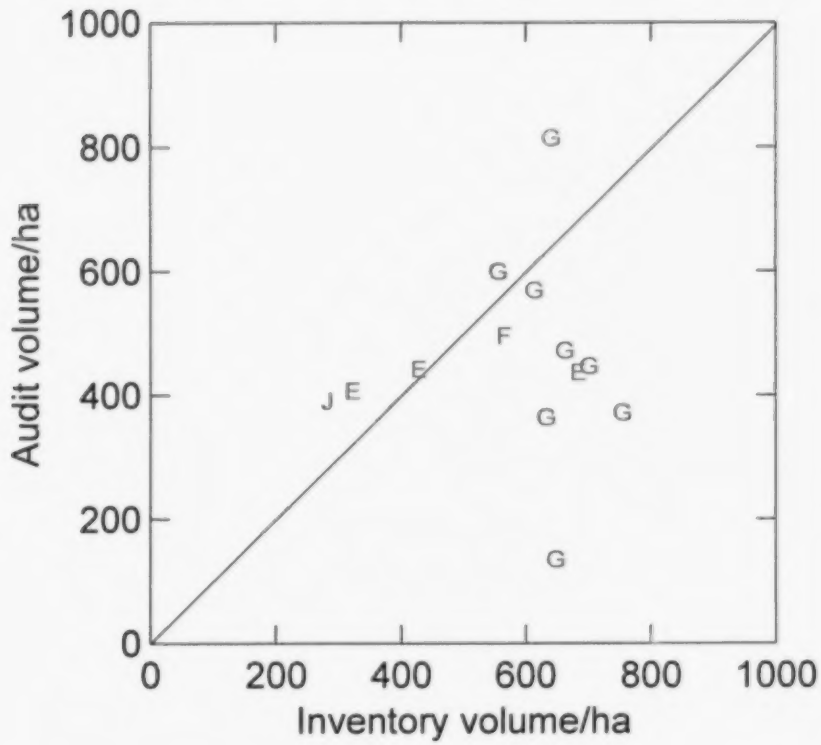
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume for operable samples.*

3. Paired T Test @ 95% (α=0.05) for operable samples (n=13)
mean difference = -119.777 m^3/ha
p - value for mean difference = 0.060
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for operable samples by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @ 95% (α=0.05) for operable samples (n=13)
Correlation co-efficient r = 0.047
p value for correlation co-efficient = 0.879
∴ correlation is NOT significant

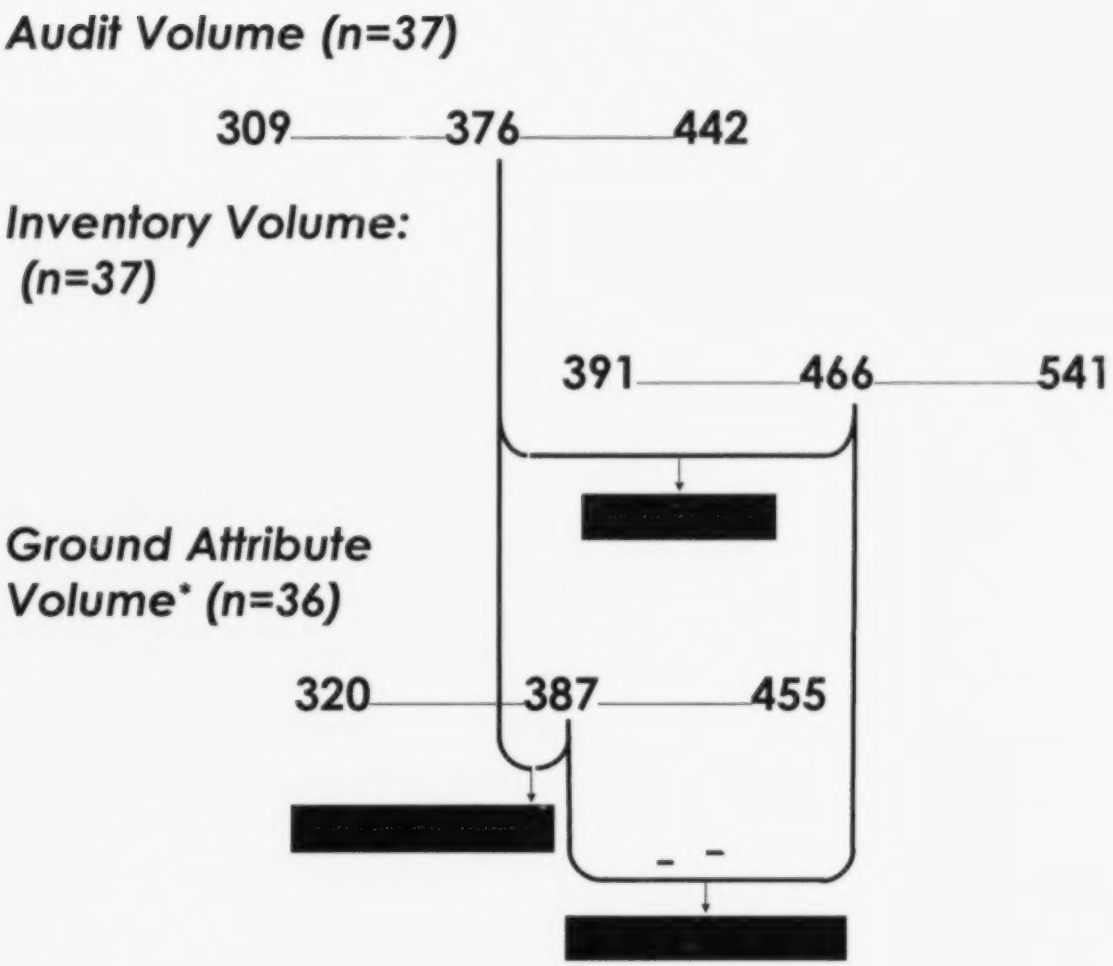
NORTH COAST TSA Inventory Audit:
Audit Volume vs. Inventory Volume (by GTG)
for Operable Samples
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Analysis Excluding 12 Suspect Samples



* "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Analysis with 12 "suspect" samples excluded

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=37)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/Tree Class 1,2)*

309 —— 376 —— 442 Audit Volume (17.7% sampling error)

391 —— 466 —— 541 Inventory Volume (map label attributes predicted in VDYP) (16.0% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.81$

1.0 ↓

0.65 —— 0.81 —— 0.96

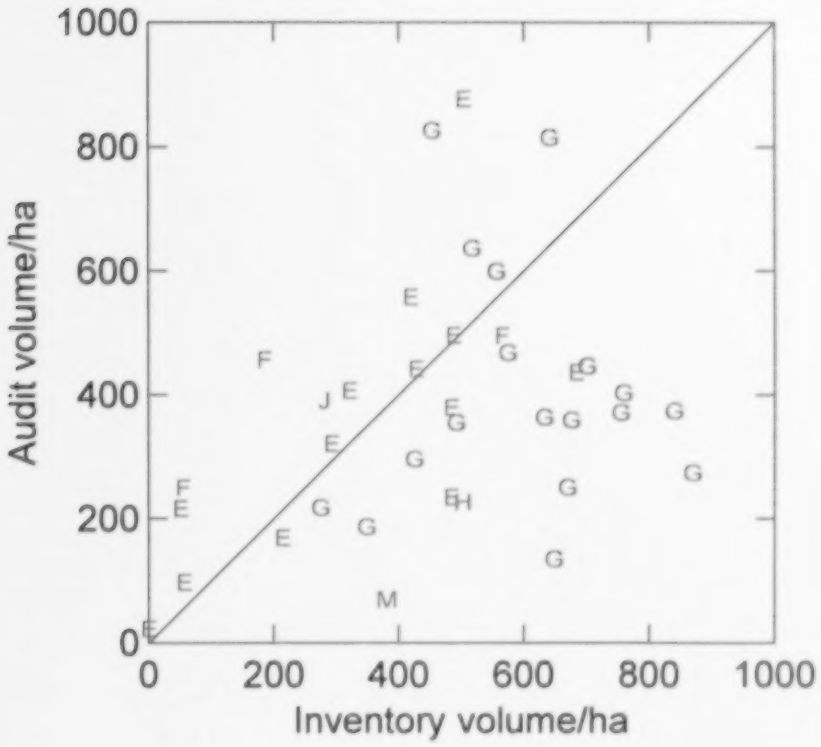
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
   mean difference = -90.246 m^3/ha
   p - value for mean difference = 0.030
   **since p-value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
   There was a significant difference within GTG G.
   (for GTG G: mean difference = -192.411; p-value = 0.005; n=18)

5. Correlation @ 95% (α=0.05) for all samples
   Correlation co-efficient r = 0.347
   p value for correlation co-efficient = 0.035
   .: correlation is significant

NORTH COAST TSA Inventory Audit:
"Suspect" samples excluded
Audit Volume vs. Inventory Volume (by GTG)
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Analysis with 12 "suspect" samples excluded

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): *"VDYP model" bias (n=36*)*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only /Tree class 1,2))*

307——375——444 Audit Volume (n=36) (18.2% sampling error)

320——387——455 Ground Attribute Volume (predicted in VDYP) (17.5% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 0.97$$

1.0 ↓

0.84——0.97——1.10

* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -11.928 m^3/ha
p - value for mean difference = 0.636
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG F.
(for GTG F: mean difference = 63.9; p-value = 0.040; n=3)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.724
p - value for correlation co-efficient < 0.001
.: correlation is significant

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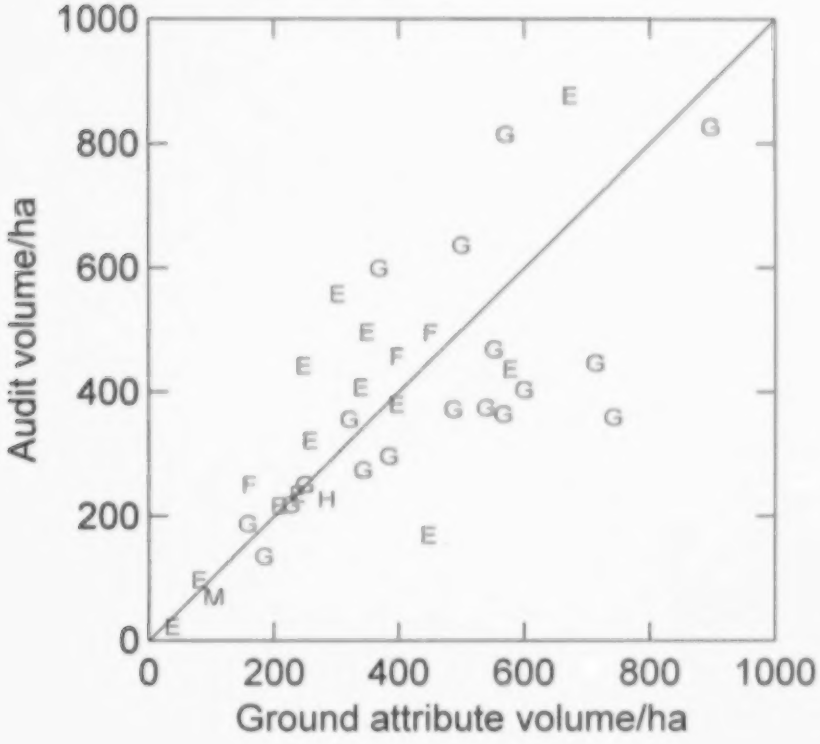
* Top height (and hence ground attribute volume) was not available for 1 sample. All statistics on this page are based on the 36 samples for which both an audit volume and a ground attribute volume was available.

NORTH COAST TSA Inventory Audit:
"Suspect" samples excluded
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Analysis with 12 "suspect" samples excluded

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): *"Attribute" Bias (n=36*)*

1. Average volumes/ha and confidence interval @ 95%

(Utilization level : 17.5 cm + net merch. less decay only, Tree Class 1,2))

320 ——— 387 ——— 455

Ground Attribute Volume
(predicted in VDYP)
(17.5% sampling error)

395 ——— 471 ——— 547

Inventory Volume (n=36)
(map label attributes predicted in VDYP)
(16.1% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.82$$

1.0
↓

0.69 ——— 0.82 ——— 0.95

** The ratio indicates that there is a significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -83.847 m^3/ha
p - value for mean difference = 0.016
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were significant differences within GTGs E and G.
(for GTG E: mean difference = -86.308; p-value < 0.001; n=13
for GTG G: mean difference = -37.111; p-value = 0.022; n=18)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.571
p - value for correlation co-efficient < 0.001

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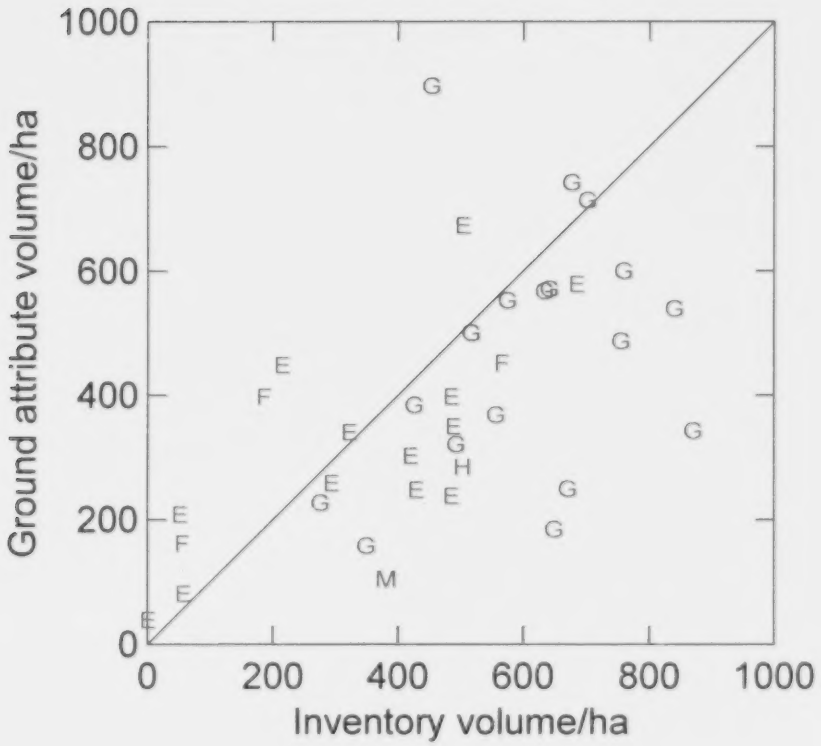
* Top height (and hence ground attribute volume) was not available for 1 sample. All statistics on this page are based on the 36 samples for which both an inventory volume and a ground attribute volume was available.

∴ correlation is significant

NORTH COAST TSA Inventory Audit:
"Suspect" samples excluded
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Inventory Classification Assessment

- 51% of the growth type groups from the inventory (ie. map labels) matched the audit growth type groups.
- the growth type group distribution for the 49 inventory audit samples is as follows (the bold italic entries on the diagonal in the table indicate a GTG match between the audit and the inventory):

Audit GTG	***Inventory GTG (columns)***						
(rows)	E	F	G	H	J	M	*total*
E	***13***	0	12	0	0	1	26
F	0	***1***	4	1	1	0	7
G	2	2	***11***	1	0	0	16
H	0	0	0	***0***	0	0	0
J	0	0	0	0	***0***	0	0
M	0	0	0	0	0	***0***	0
total	15	3	27	2	1	1	**49**

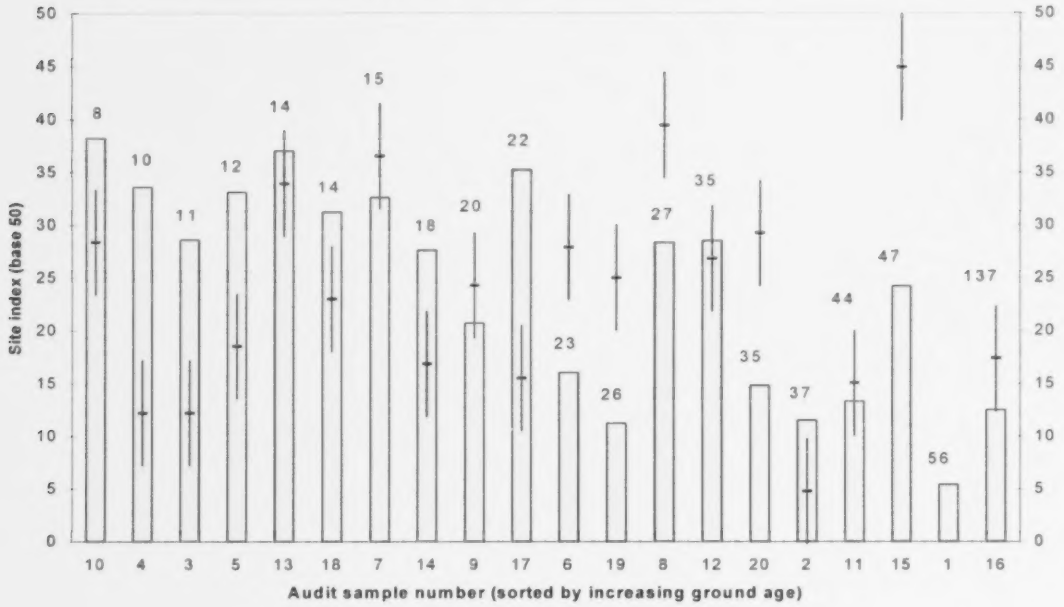
Letter symbols correspond to GTG's as follows:

E	*Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH*	H	*B, BH, BS*
F	*H, HDecid.*	J	*SF, SH (and SC), SB*
G	*HFd, HL, HPy, HPw, HPl, HCw, HB, HS*	M	*Pl F, Pl S (and Pl B)*

Immature Site Index and Classification Assessment

- **39%** of the growth type group assignments from the inventory (ie. map labels) matched the corresponding audit growth type group assignment.

NORTH COAST TSA Inventory Audit:
Comparison of Inventory and Audit Site Index for Immature Samples



Notes:

- shaded bars correspond to ***audit site index*** values
- tick marks on vertical lines represent ***inventory site index*** (vertical lines have arbitrarily been set at ±5m around site index)
- numbers at the top of the bars corresponds to ground total age
- audit site indices use BH age and growth intercept SI where available (from SiteTool)
- one sample was classed as NSR on the inventory
- one sample was found to be mature (on the inventory files and by the audit sample)
- inventory site index was within 5 m of the audit site index for 5 out of the remaining 18 samples (inventory site index was more than 5m higher than the audit site index for 5 samples and more than 5m lower than the audit SI for 8 samples)
- audit TH species did not match inventory leading species for 8 samples (#10, 5,18,17,19,8,12, and 15); no alternate spp. SI data was available